Defect repair of EUV absorber layer using low acceleration voltage FIB-GAE

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Introduction

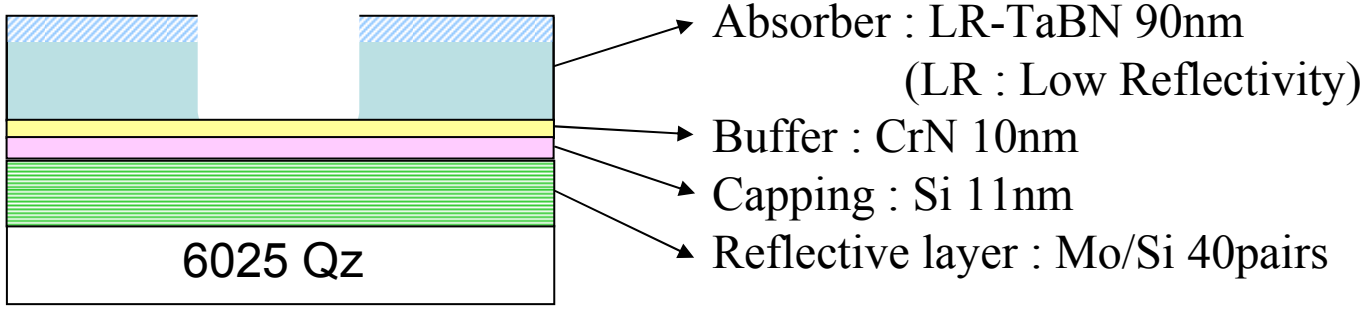
- Technical Issues of EUV mask fabrication process
  - •Zero defect mask
    - •Low defect process
    - •Defect inspection
    - •Defect repair
  - •High accuracy CD control
  - •Low damage process for reflective layer

- Defect repair technique for ordinary photomask
  - •Laser zapper
  - •FIB-GAE (Focused ion beam – Gas assist etching)
  - •EB-GAE (Electron beam – Gas assist etching)
  - •AFM nano-machining

➡ In this work, FIB-GAE technique was evaluated for EUV mask absorber defect repair

Experimental

- TEST Sample
  - ✓Sample structure (HOYA blank)



  - ✓Resist patterning : 50kV EB with PCAR
  - ✓Absorber dry etching : 2step process (CF4 base gas => Cl2 base gas)
  - ✓Buffer dry etching : Cl2, O2 mixture gas process
- Repair tool SIR-7
- Mask metrology tool
  - ✓CD-SEM KLA8250R(KLA-Tencor)
  - ✓AFM Dimension X3D(Veeco)
- Exposure tool MET @ Berkeley

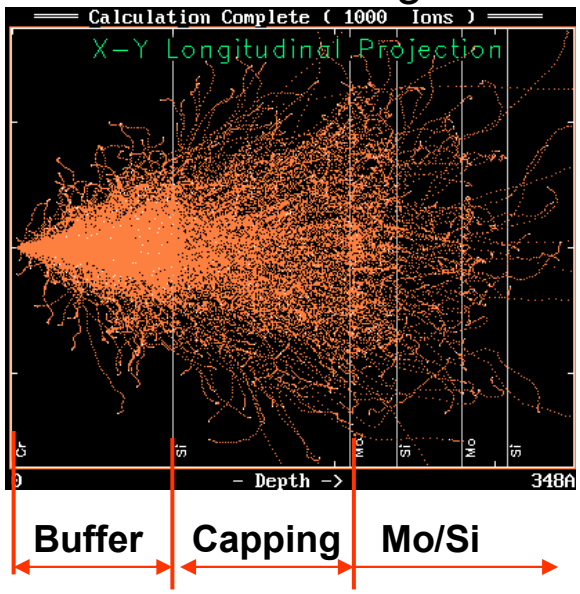
Low acceleration voltage FIB

★ Advantage of low acceleration voltage FIB

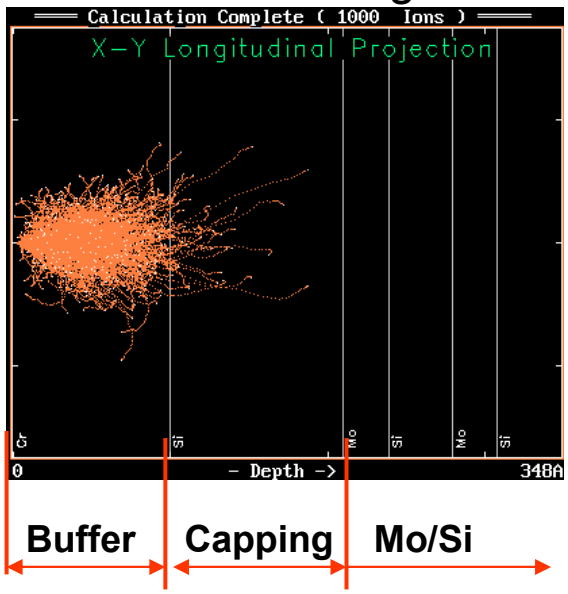
- High throughput (4~5 times faster than AFM nano-machining)
- Smaller surface damage and Ga ion implantation are expected than conventional FIB

Simulation results of Ga ion implantation on EUV mask surface

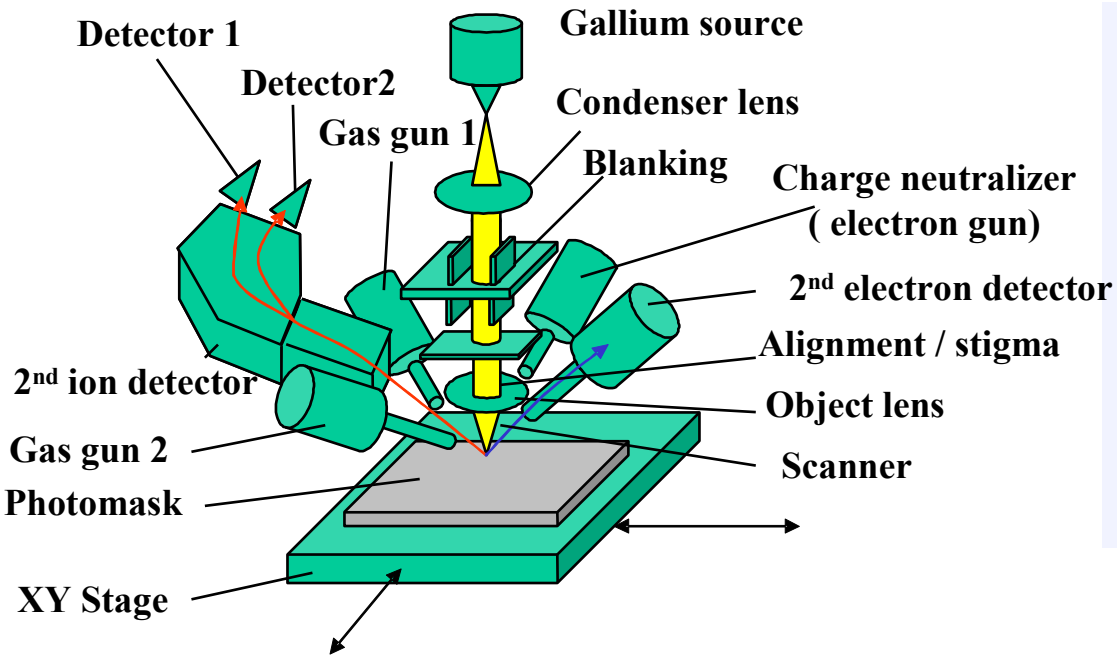
Acceleration voltage 30kV



Acceleration voltage 10kV



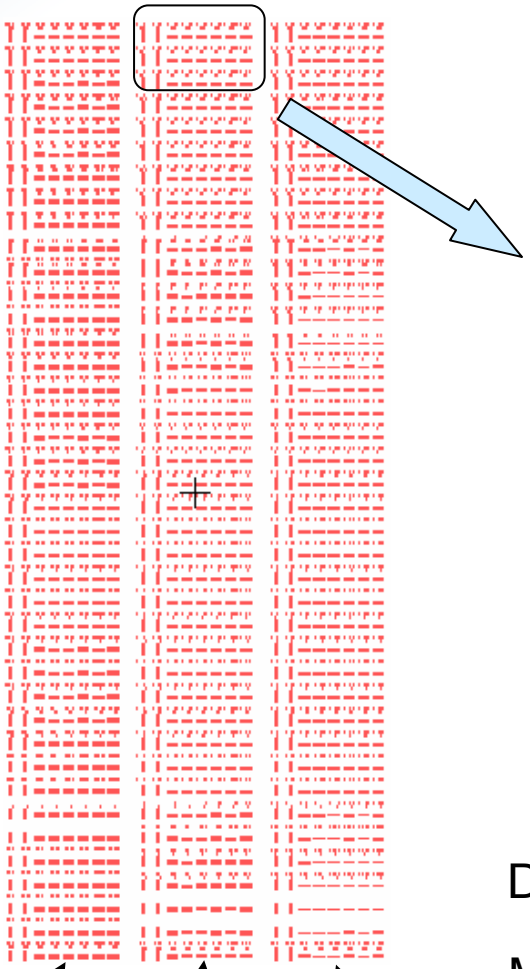
Low acceleration voltage FIB photomask repair tool : SIR-7



SIR-7

Acceleration voltage 10kV

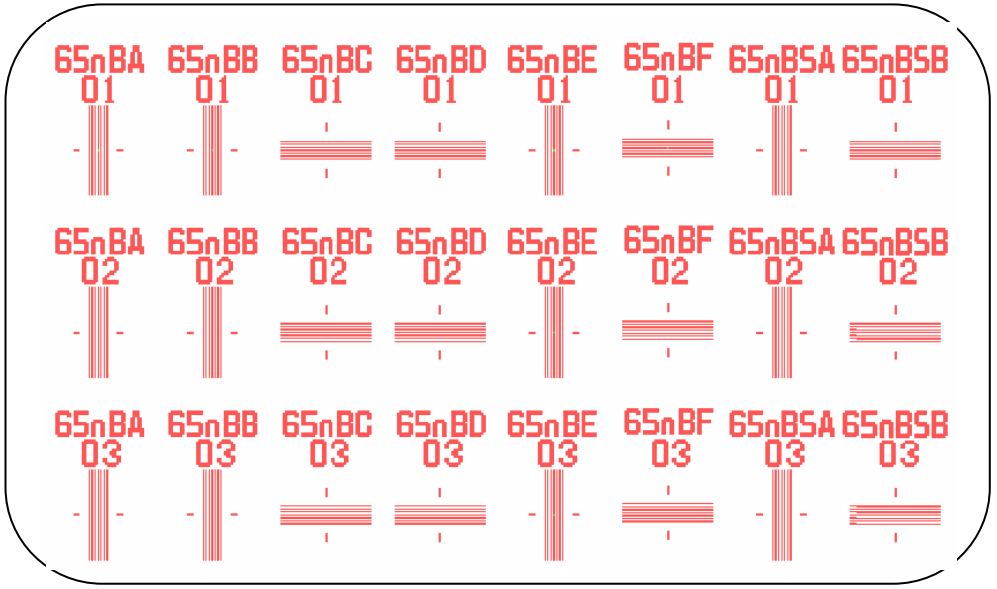
Defect repair test pattern



450nm (90nm)
325nm (65nm)
225nm (45nm)

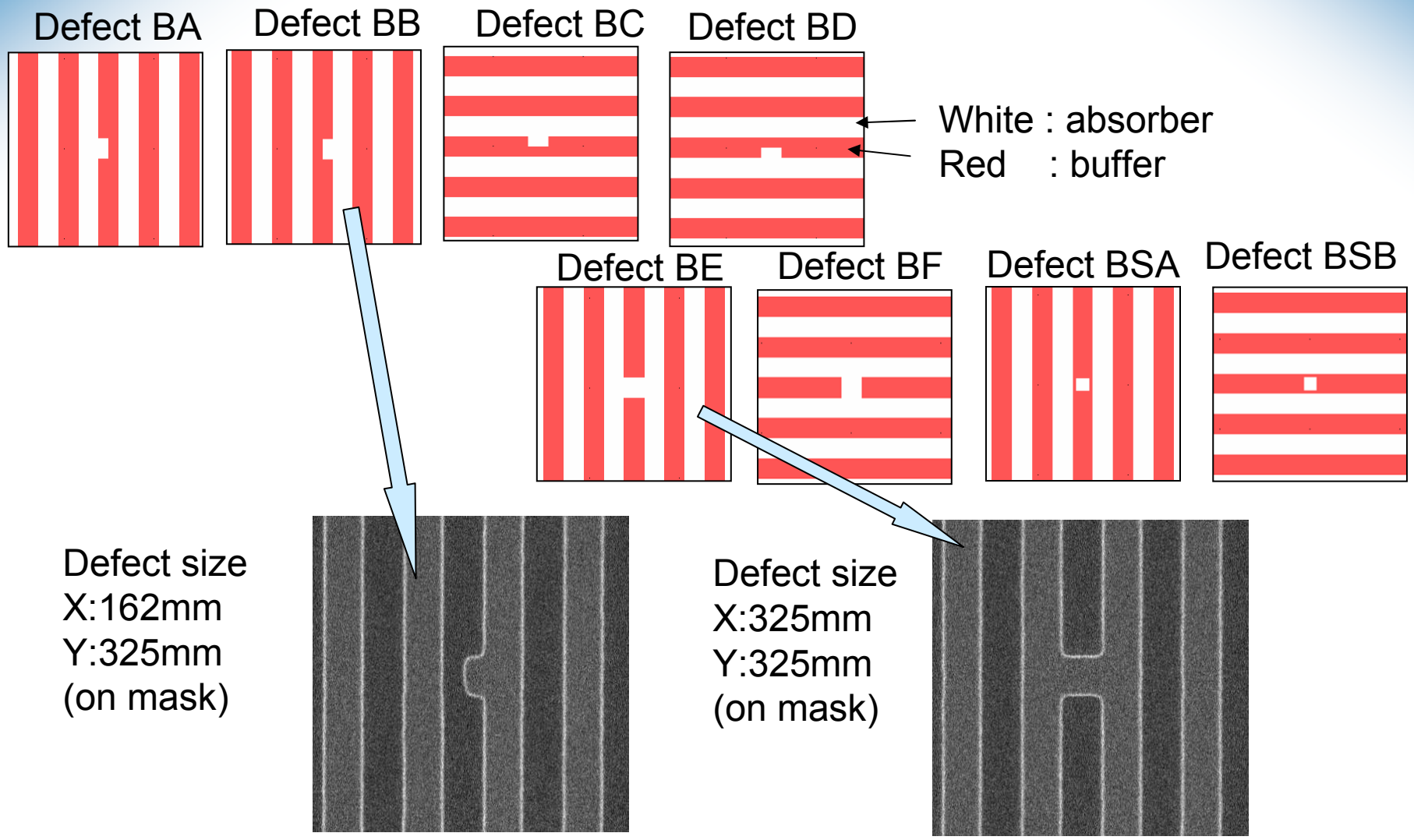
Main pattern size on mask (on wafer)

- 3 main pattern size and 8 type defect were prepared.
- Main pattern size of 65nm(on wafer) was used for defect repair test



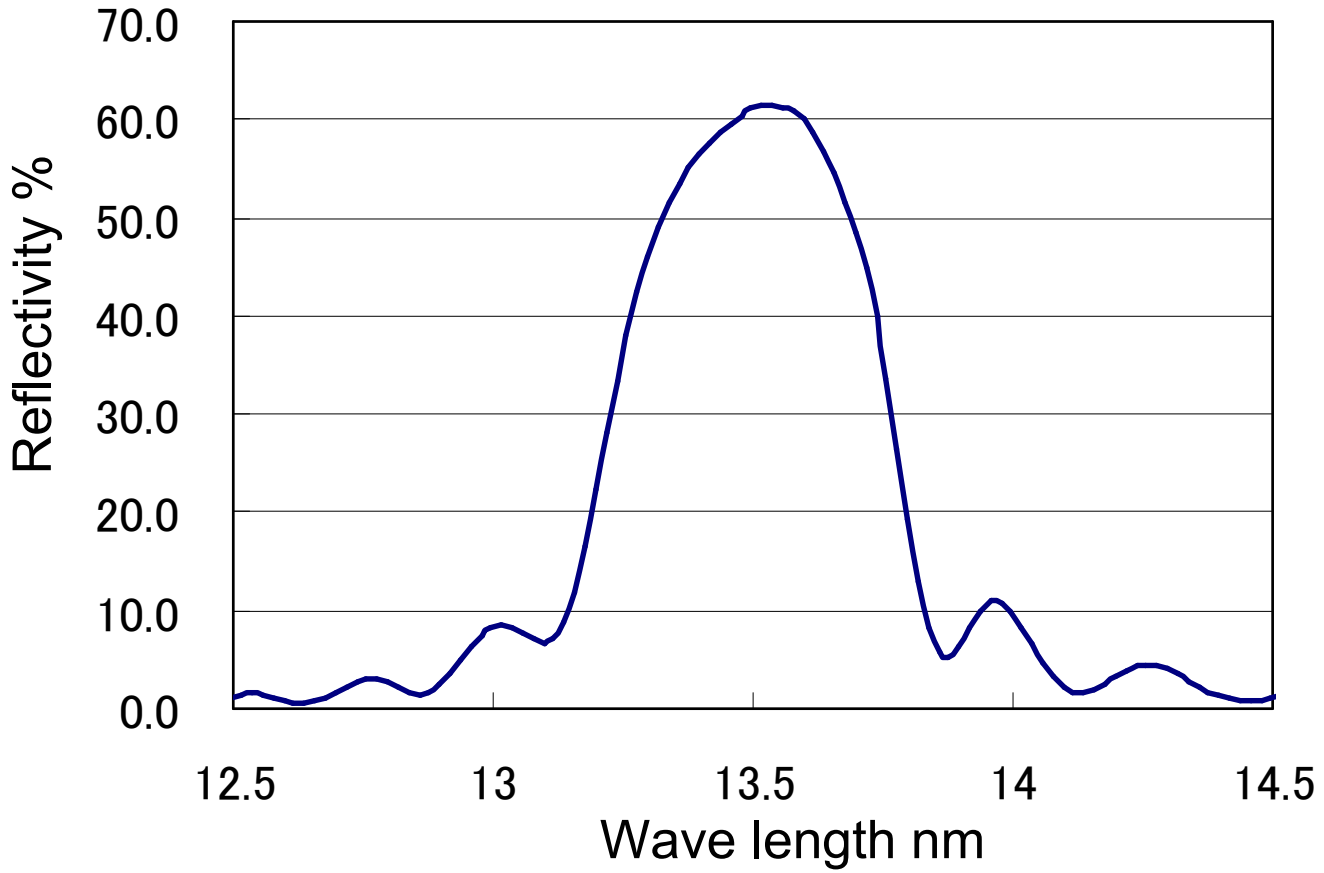
Defect type : BA~BF, BSA~BSB

Program defect pattern



"defect BB" (protrusion) and "defect BE" (bridge) were used for defect repair test

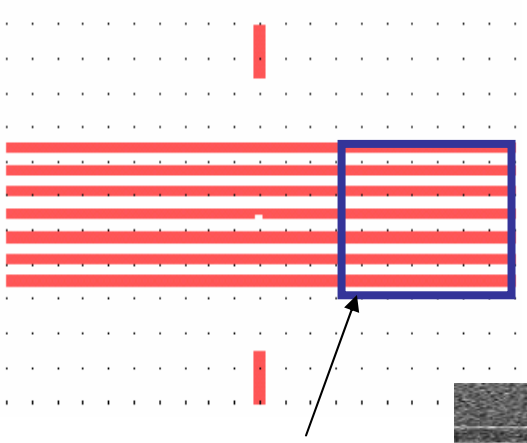
EUV reflectivity curve of the EUV mask



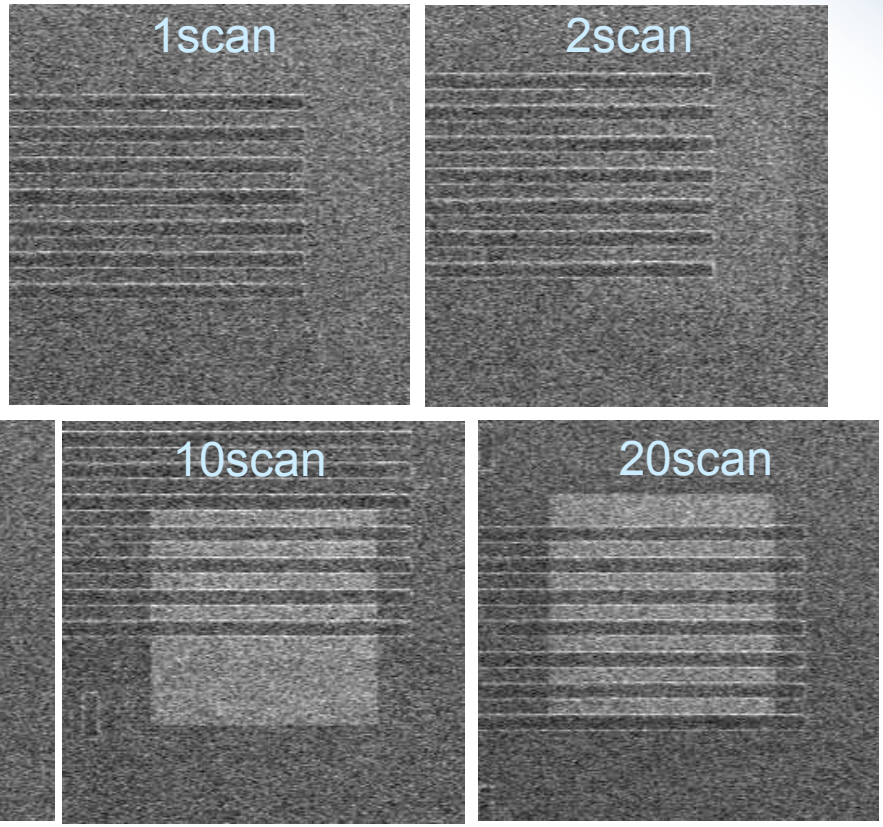
Peak reflectivity 61.55%
Centroid wave length 13.5nm

FIB scan damage of absorber film

SEM images (before buffer etch)



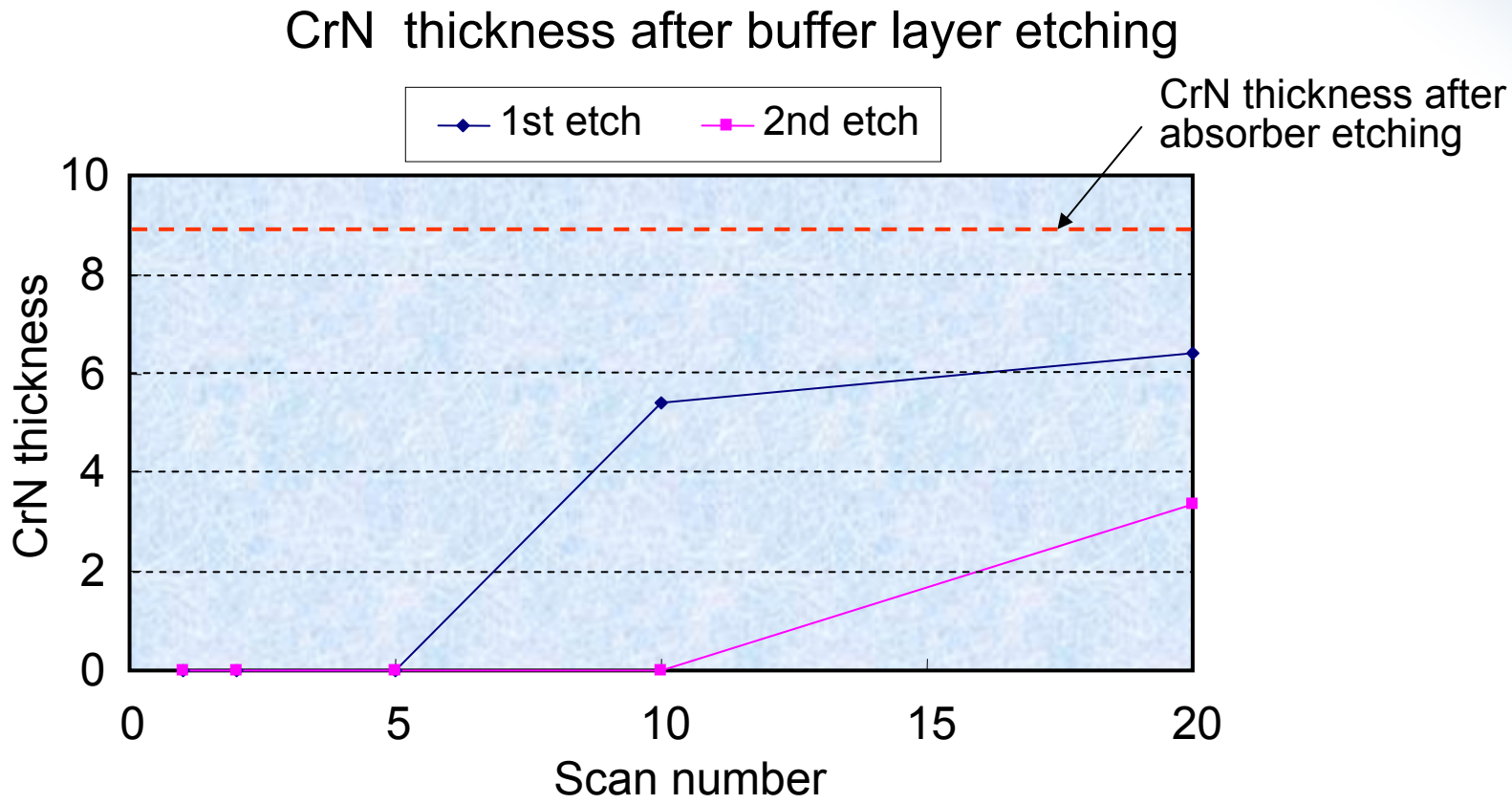
Test scan area



SEM image contrast was clearly different at FIB scan area.
Absorber damage of 20scan was about 1nm.

FIB scan damage of buffer film

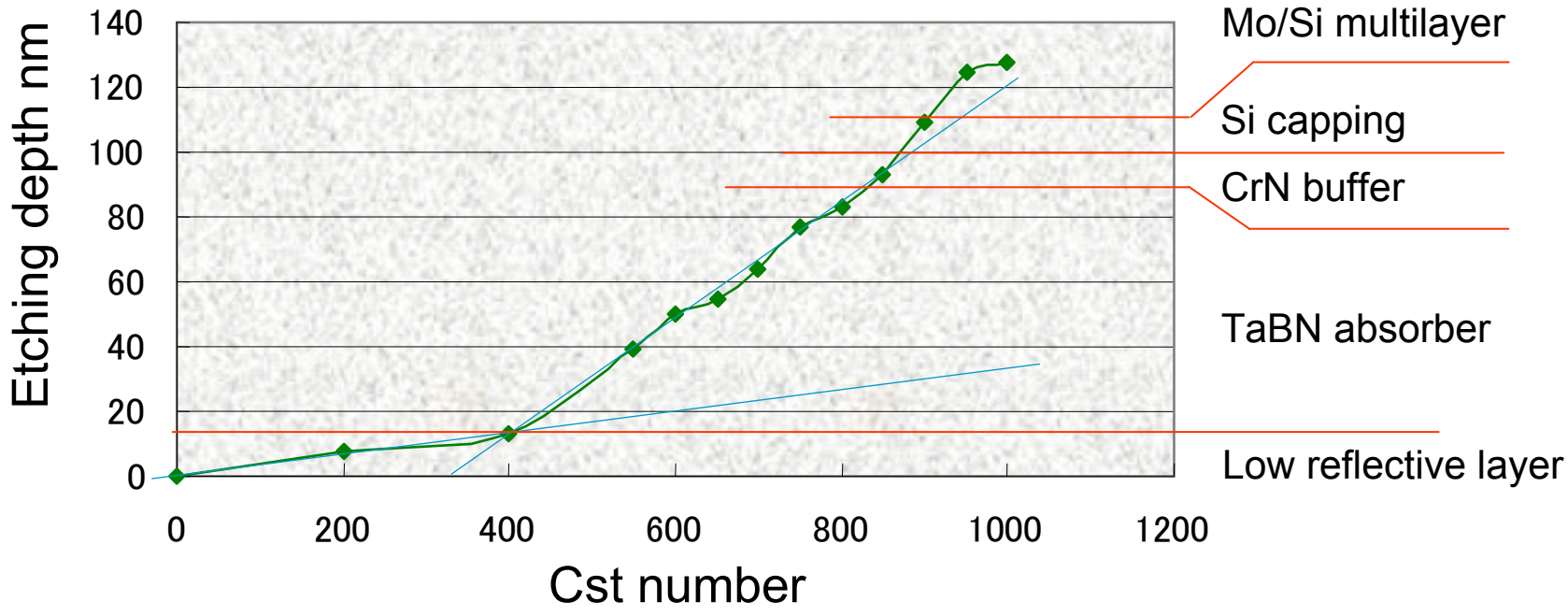
(Influence of Ga ion to buffer layer etching)



- Implanted Ga ion prevents CrN buffer layer etching.
- CrN remains at >5 scan region after buffer layer etching.

(Scan number should be smaller than 5 in present buffer etching condition.)

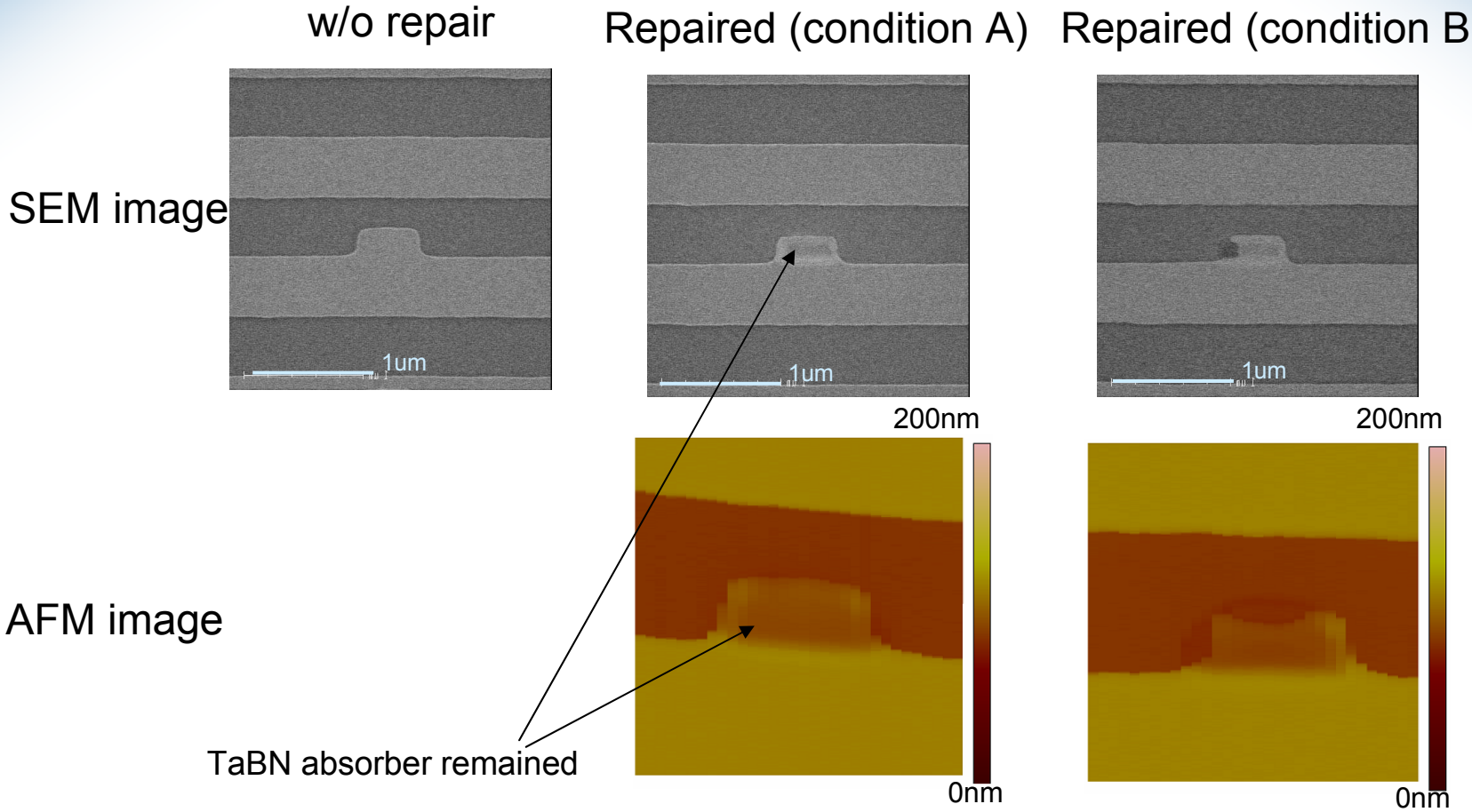
Etching rate of low acceleration FIB-GAE



(Cst : Critical scan time)

Defect repair test (1st trial)

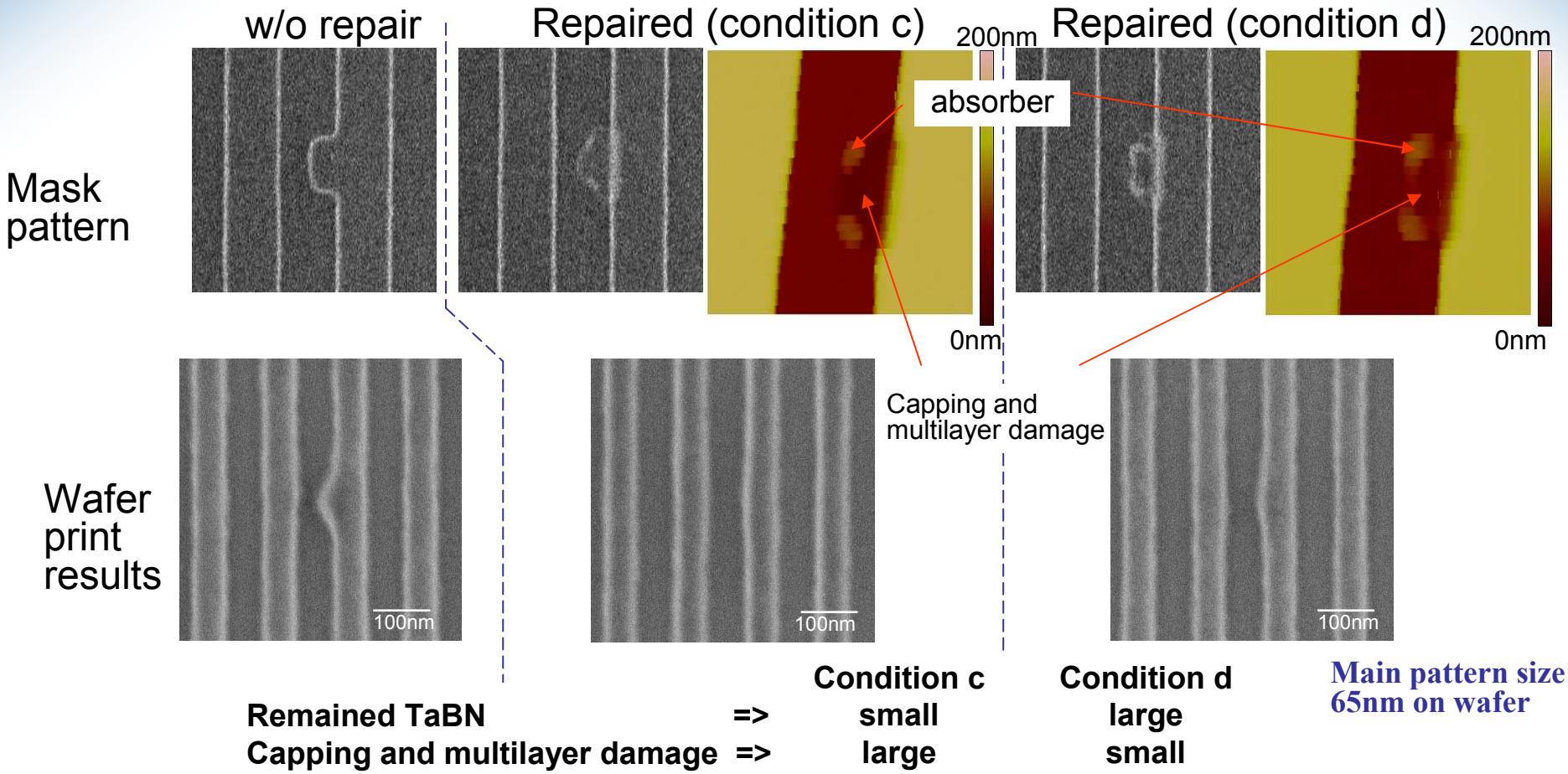
Main pattern size 100nm on wafer



- Absorber etching was short and absorber defect remained at repair region.
- 20~30nm absorber + buffer remained after buffer etch. (Remained TaBN absorber was not etched during the buffer etching)

Defect repair test (2nd trial: Protrusion defect)

FIB scan algorism was modified for TaBN etching

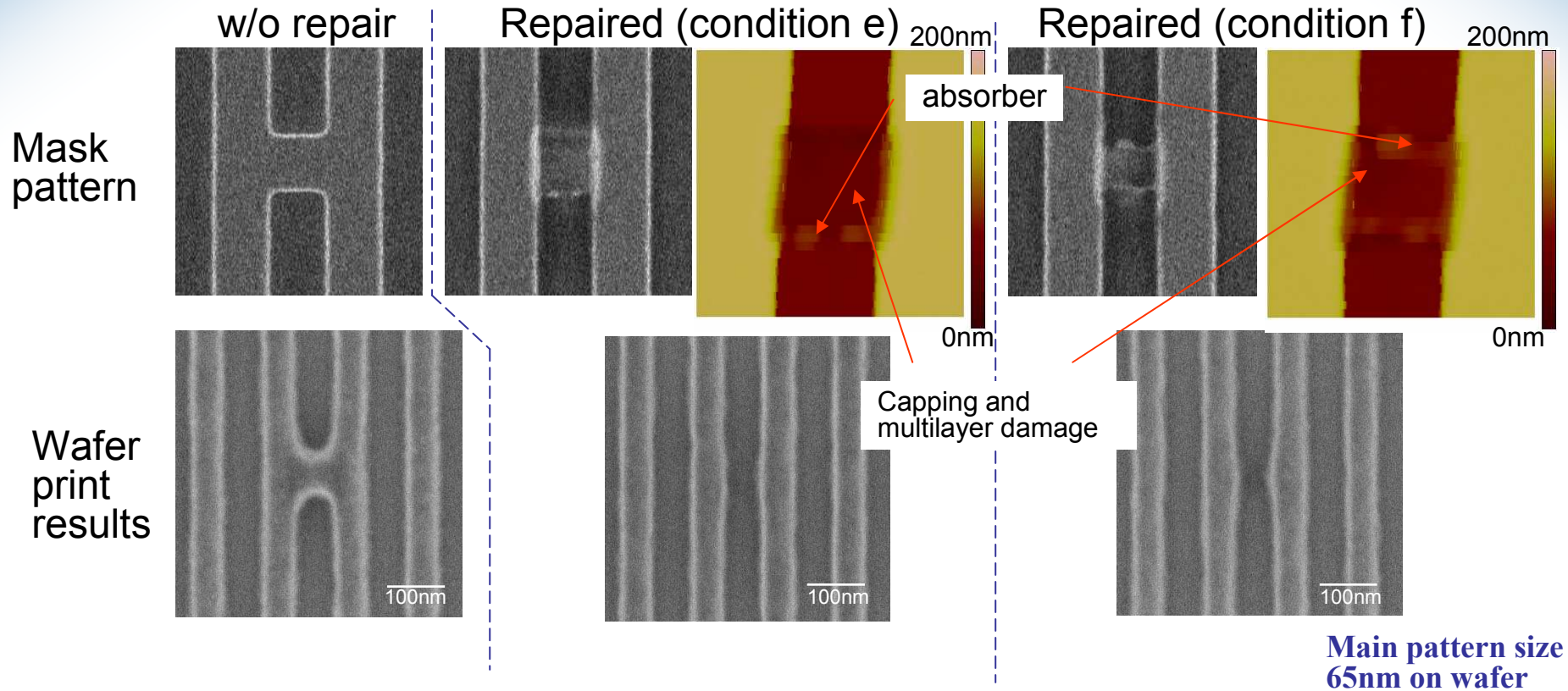


		Condition c	Condition d
Remained TaBN	**=>**	**small**	**large**
Capping and multilayer damage	**=>**	**large**	**small**

Main pattern size 65nm on wafer

•Remained absorber affected to wafer print result more than multilayer damage.

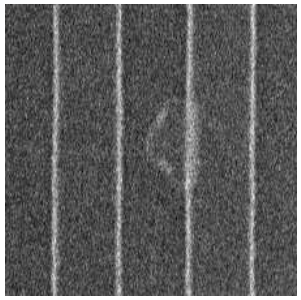
Defect repair test (2nd trial: Bridge defect)

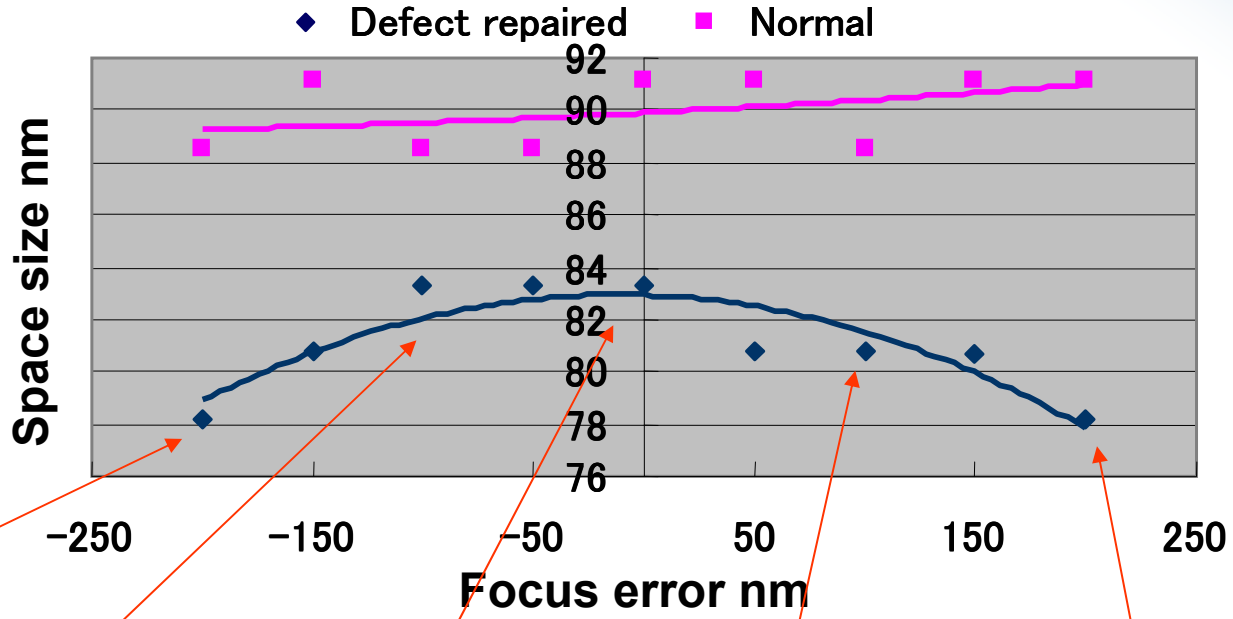


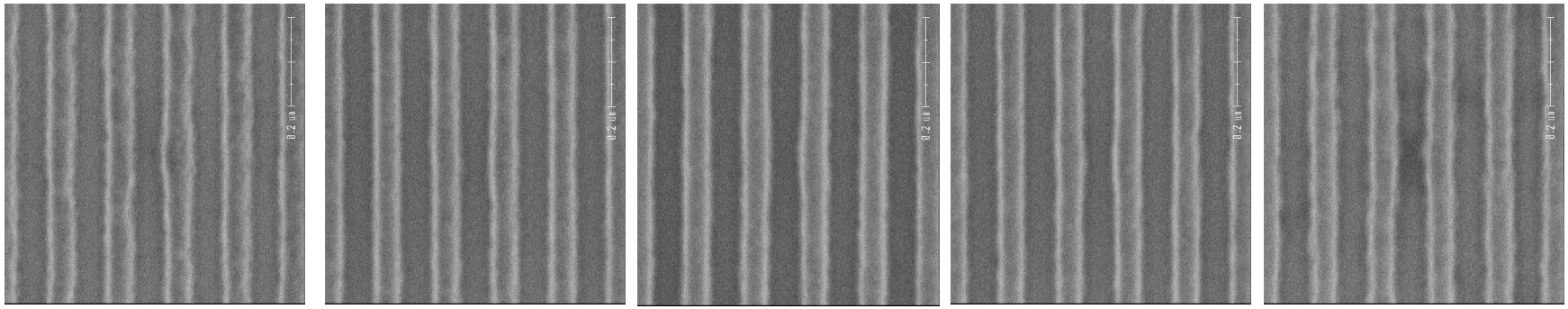
Main pattern size 65nm on wafer

		Condition e	Condition f
Remained TaBN	=>	small	large
Capping and multilayer damage	=>	large	small

DOF curve of defect repair region


Mask





Space size was calculated from SEM images using inhouse edge detect software

Summary

Defect repair of absorber layer pattern was tested using low acceleration voltage FIB-GAE

- Pattern edge of the defect remained after defect repair.
  - ➡ We are modifying defect repair algorism now
- One or two pair of Mo/Si multilayer was damaged.
  - ➡ Assist gas evaluation for higher buffer selectivity is necessary for damage less repair (future work)
- Remained absorber affected to wafer print result more than multilayer damage.
- We think good wafer print results was obtained as a preliminary repair test and low acceleration voltage FIB-GAE is promising technology for EUV mask defect repair.

Acknowledgement

- This work was supported by New Energy and Industrial Technology Development Organization (NEDO) .
- We would like to thank
  - SEMATECH for giving us an opportunity of MET use.
  - CXRO group at Lawrence Berkeley National Laboratory for helping wafer print test using MET.